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Glass Comparisons Using a Computerized Refractive Index Data Base

Refractive index and density are two physical properties of glasses that are used in making comparisons of known and questioned samples. Also, the dispersion of the samples can be calculated from the refractive indices. The methods for determining the values of the refractive index and dispersion have been described by previous authors [*1-4*].

The purpose of this paper is to show one way of improving the reproducibility of the results obtained from the refractive index determinations by the use of the computer.

Measurement of Refractive Index and Dispersion

The refractive index of the glass is measured by the Becke line method. Because of the small size of the samples generally received in a crime laboratory, the use of a precision refractometer is ruled out.

In the Becke line method, the glass is immersed in a liquid that has a higher refractive index than the glass, and the preparation is heated on a calibrated hot stage. The rate of change of the refractive index n with respect to temperature T (dn/dt) of the glass is approximately −0.0005, while the rate of change of the refractive index with respect to temperature of the glass is approximately −0.00001. However, no correction for the dn/dt of the glass is used because both the known and questioned glass samples are immersed in the same liquid, on the same microscope slide, and the refractive indices are compared.

The refractive index of the glass also varies with the wavelength of light used to illuminate the sample. This variation is called the dispersion of the glass. This value can be determined for any sample of glass if the values of the refractive index are measured at 486.1, 589.3, and 656.3 nm. The value of the dispersion is most often expressed as

$$\gamma = (n_D - 1)/(n_F - n_C) \qquad (1)$$

where

γ = dispersion,
n_D = refractive index of a substance at 589.3 nm,
n_F = refractive index of a substance at 486.1 nm, and
n_C = refractive index of a substance at 656.3 nm,

or the dispersion can be shown as a plot of these indices.

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Equipment

Because of the variations in the properties of glasses decreasing steadily as a result of increased quality control [*1,5*], it is necessary to use precise methods in determining the refractive index of the glasses. The equipment used is a Mettler FP-2 hot stage, a Nikon LK-E microscope fitted with the extra-long-working-distance phase condenser, and a BM ×10 phase objective. Figure 1 shows this equipment. Phase contrast microscopy is used because the Becke lines are more clearly visible. This improved visibility makes it easier to determine the match point. In using the extra-long-working-distance condenser, a problem arises in that the tube above the condenser is too long and it therefore interferes with the illumination of the microscope. This is solved by eliminating the long tube on the condenser and inserting a +2 portrait lens above the condenser, thus allowing Koehler illumination to be achieved.

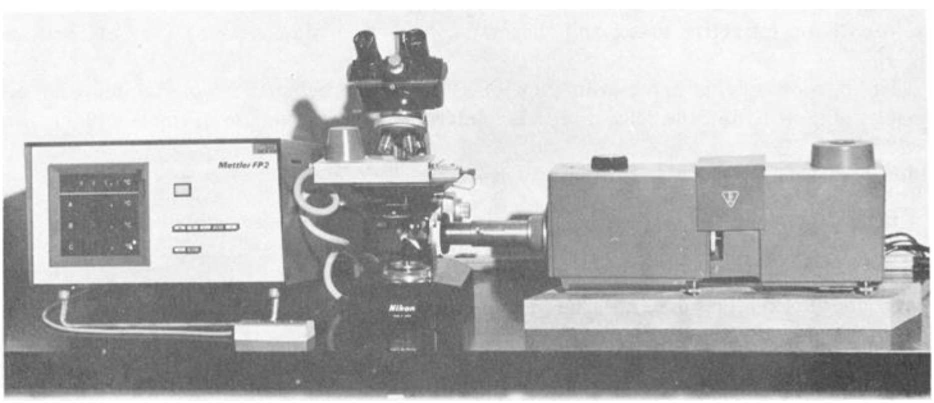

FIG. 1—*Equipment used in performing glass comparisons.*

The illumination is provided by a B & L grating monochromator equipped with a quartz-iodide-tungsten light source and the visible grating. The variable slit assembly is also used, as it provides a very rapid method for adjusting the slit width and thus makes it easier to observe the Becke lines. A quartz condensing lens must also be used with the monochromator to provide sufficient illumination for the microscope.

A set of Cargille calibrated immersion liquids[2] is used. Hartmann net graph paper[2] is used when the data are manually plotted. This paper is not needed when the computer is used.

Procedure

In performing glass comparisons the first step, if the size of the samples is sufficient, is to place some of the fragments of the known and questioned samples in a density gradient tube. While the samples in the tube are reaching equilibrium, the known glass is used to determine the immersion liquid that matches the index of the glass in the red region of the spectrum at room temperature. If the known and questioned fragments are similar with respect to density, the refractive indices of the samples are compared.

[2] R. P. Cargille Laboratories, Inc., 33 Factory St., Cedar Grove, N.J.

The procedure used is known as the Emmon's double variation method [4]. The known and questioned glass fragments are collected from the density tube and small fragments (approximately 1 mm^2 or less) of both known and questioned glass are placed on a microscope slide. Immersion oil, with a refractive index of 0.004 units higher than the liquid that matches in the red, is added to the preparation.

The slide is then inserted into the hot stage and the preparation is heated until the Becke line is barely visible in the red region of the spectrum. The temperature is then held constant and the monochromator is adjusted until a match is obtained. The temperature and the average of ten wavelength readings are recorded and the same procedure is followed in the orange, green, and blue regions of the spectrum. When the four sets of data are obtained, the comparison of the two samples is completed. This procedure is performed in a small darkened room to make the observations easier for the analyst.

To calculate the actual refractive index and the dispersion of the glass, without the computer program, it is necessary to plot the temperature and wavelength values on Hartmann dispersion net and construct the best straight line through these points (see Fig. 2). Next, from this line, the three temperatures for the match points at the C, D,

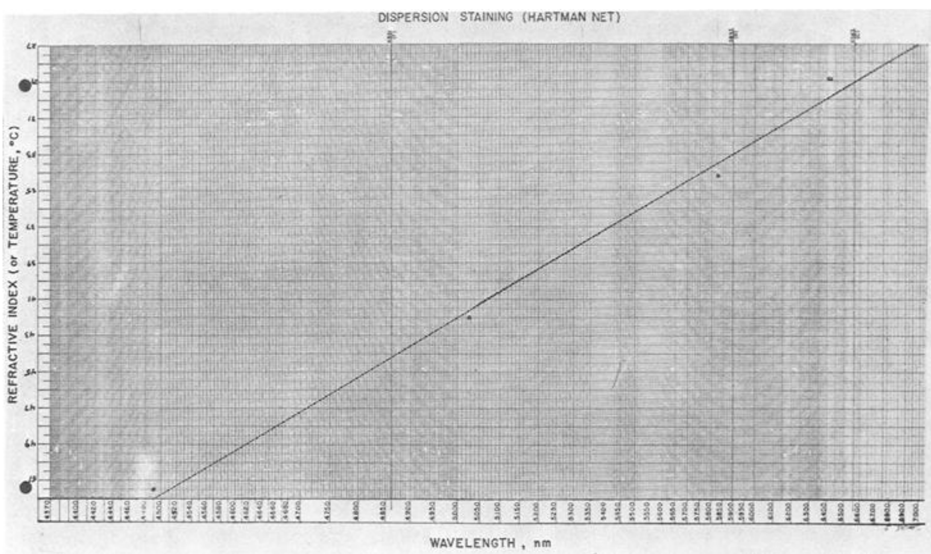

FIG. 2—*Example of dispersion curve plotted manually.*

and F lines can be interpolated. These three temperatures can be used in the following formula to determine the value of n_C, $n_{D'}$, and $n_{F'}$:

$$n_\lambda{}^t \text{ glass} = n_\lambda{}^{25°} \text{ liquid} + \mathrm{d}n/\mathrm{d}t \text{ liquid } (t - 25°) \quad (2)$$

These values are then substituted in the dispersion formula to determine the value of the dispersion for the sample.

To simplify the steps described in determining the values for the refractive index and dispersion, a computer program has been developed that performs all of the necessary calculations and thus eliminates manual operations.

The four sets of temperature/wavelength match points are entered into the computer, along with the data concerning the immersion liquid used. From these data the computer plots the points, constructs the curve through these points, and determines the temperatures from the match points at the C, D, and F lines. It then computes the corrected values of the refractive index of the glass at these three points, substitutes these values into the dispersion formula, computes the value of the dispersion of the glass, and prints out all of the calculated data (see Fig. 3).

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                 FLORIDA DEPARTMENT OF LAW ENFORCEMENT
                        CRIME LAB GLASS SYSTEM

SAMPLE NO.   12     ID INFORMATION MC CRONE 8271

LIQUID NO.   69     NC = 1.5900      ND = 1.5960      NF = 1.6116  DI = .00040

        T1 = 48.700            L1 =  6421.           A1 =   -81.43799254

        T2 = 50.800            L2 =  5979.           A2 =     0.11412065

        T3 = 57.000            L3 =  5371.           A3 = -.25619944D-04

        T4 = 67.100            L4 =  4592.           A4 = 0.17447998D-08

        TF =  63.604         LF = 4861.             NF = 1.59636

        TD =  51.482         LD = 5893.             ND = 1.58541

        TC =  48.629         LC = 6563.             NC = 1.58055

      DISPERSION =  37.02780             DENSITY RANGE
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FIG. 3—*Example of computer printout.*

Discussion

Three factors have been noted that play an important role in the computed values of the refractive indices obtained from the examinations. These factors are the experience of the analyst performing the Becke line observations, the immersion oil used, and the manual construction of the curve through the points on the Hartmann net to obtain the calculated values of the refractive indices of the glass.

The correct values that are to be used for the immersion liquids can be determined with a constant temperature bath, a set of interference filters or a monochromator, and a precision refractometer.

It was hypothesized that substituting a computer for the manual construction of the curve would greatly increase the reproducibility of the results obtained.

Several samples of glass with known refractive indices were obtained and the Emmon's method was used to obtain the necessary data. Next, these data were manually plotted on Hartmann net and the curves constructed on two different dates. The necessary temperatures were interpolated and used in calculating the refractive indices of the glass. The data were also given to the data center and were computed on two different dates.

TABLE 1—*Comparison of the reproducibility of the results obtained from the manual plotting of the data and from the computer processing of the data.*

		Manual				Computer	
		Run 1		Run 2			
Sample	Actual	Graph	Error	Graph	Error	Runs 1 and 2	Error
1 C	1.51484	1.50617	−0.00867	1.51536	+0.00052	1.51553	+0.00069
D	1.51722	1.51775	+0.00057	1.51806	+0.00084	1.51772	+0.00050
F	1.52285	1.52408	+0.00123	1.52473	+0.00188	1.52405	+0.00120
2 C	1.51100	1.51563	+0.00462	1.51525	+0.00425	1.51794	+0.00694
D	1.51495	1.51821	+0.00326	1.51779	+0.00284	1.51778	+0.00283
F	1.52156	1.52462	+0.00306	1.52336	+0.00180	1.52477	+0.00321
3 C	1.51325	1.51435	+0.00110	1.51444	+0.00119	1.51548	+0.00223
D	1.51608	1.51687	+0.00079	1.51696	+0.00088	1.51667	+0.00059
F	1.52188	1.52275	+0.00087	1.52300	+0.00112	1.52255	+0.00067
4 C	1.51100	1.51082	−0.00018	1.51082	−0.00018	1.51127	+0.00027
D	1.51337	1.51431	+0.00094	1.51431	+0.00094	1.51413	+0.00076
F	1.52082	1.52129	+0.00047	1.52148	+0.00066	1.52141	+0.00059
5 C	1.50820	1.50838	+0.00018	1.50841	+0.00021	1.50849	+0.00029
D	1.51074	1.51073	−0.00001	1.51096	+0.00022	1.51090	+0.00016
F	1.51665	1.51706	+0.00041	1.51733	+0.00068	1.51737	+0.00072

The results of these data are given in Table 1. As can be seen, there are some differences in the values calculated manually on the two dates, whereas the results from the computer remain the same on each date.

It is not the purpose of this paper to attempt to justify the purchase of a computer entirely for use in glass comparisons; rather, it is to show how an existing computer can be used to help make the analyst's results more reproducible. Also, it is not the intent of this paper to infer that a match between the refractive index and density of two glass samples establishes identification between two samples of glass. The interpretation of the data obtained, as well as performing the refractive index determinations, is dependent on the skills and experience of the laboratory analyst. The identification significance of the results has been considered in the literature [*6–9*].

Conclusion

Whether the computer is used or the Hartmann net procedure is followed, the main element in any examination is the analyst's ability to properly perform the Becke line observations to determine the correct values of the temperatures and wavelengths. Nevertheless, the computer can provide more consistent values by elimination of the manual construction of the curve. These data, collected from experienced analysts, could perhaps in the future be placed in a large data bank to help assign statistical significance to this type of trace evidence.

Acknowledgments

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References

[*1*] Miller, E., *Journal of Forensic Sciences*, JFSCA, Vol. 10, No. 3, July 1965, pp. 272-281.
[*2*] Grabar, D. G. and principe, A. H., *Journal of Forensic Sciences*, JFSCA, Vol. 8, No. 1, Jan. 1963, pp. 54-67.
[*3*] McCrone, W. C., *Journal of the Association of Official Analytical Chemists*, Vol. 55, No. 4, 1972, pp. 834-839.
[*4*] McCrone, W. C., *Journal of the Association of Official Analytical Chemists*, Vol. 56, No. 5, Sept. 1973, pp. 1223-1226.
[*5*] Ojena, S. M. and DeForest, P. R., *Journal of Forensic Sciences*, JFSCA, Vol. 17, No. 3, July 1972, pp. 315-329.
[*6*] Dabbs, N. D. G., *Journal of Forensic Sciences*, JFSCA, Vol. 16, No. 1, Jan. 1972, pp. 70-78.
[*7*] Dabbs, M. D. G., *Journal of the Forensic Science Society*, Vol. 8, 1968, pp. 71-72.
[*8*] Nickolls, L. C., *Journal of the Forensic Science Society*, Vol. 6, 1966, pp. 180-182.
[*9*] Kirk, Paul L., *Crime Investigation*, Interscience Publishers, Inc., New York, 1953, pp. 243-245.

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